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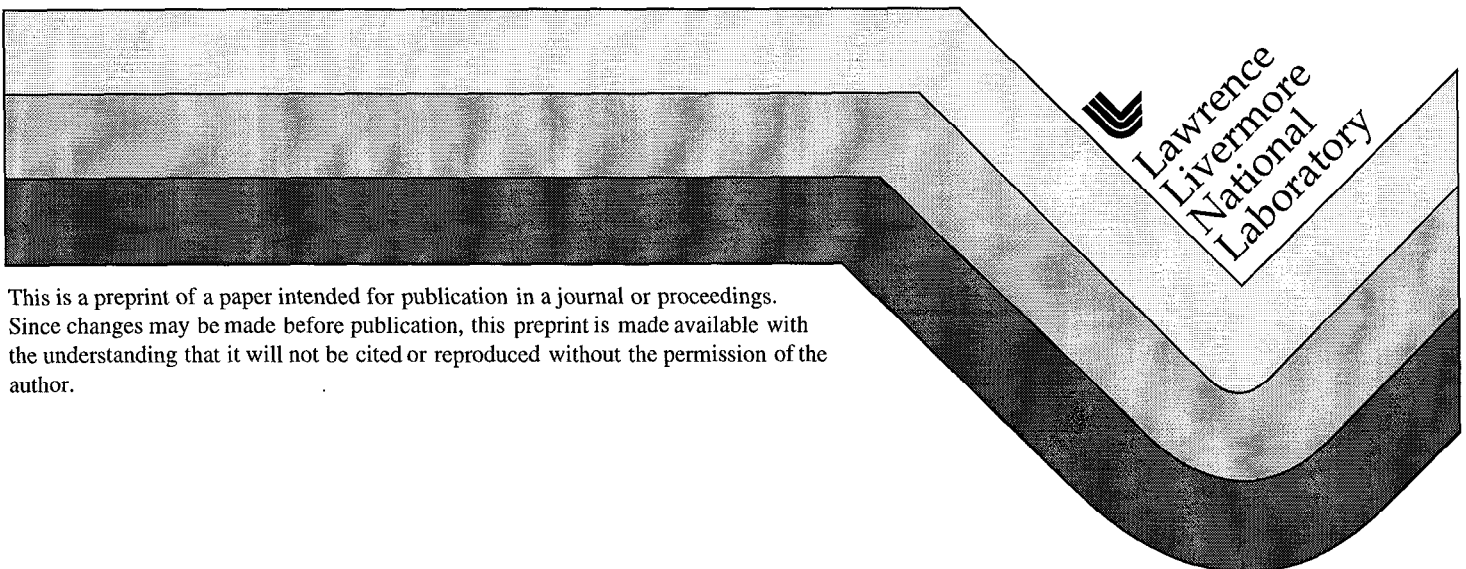
PREPRINT

The National Wildfire Prediction Program: A Key Piece of the Wildfire Solution

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This paper was prepared for submittal to the
Joint Fire Science Conference and Workshop;
Crossing the Millennium:
Integrating Spatial Technologies and Ecological Principles for a New Age in Fire Management

July 1999



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THE NATIONAL WILDFIRE PREDICTION PROGRAM: A KEY PIECE OF THE WILDFIRE SOLUTION

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ABSTRACT

Lawrence Livermore National Laboratory and Los Alamos National Laboratory have developed an initiative for a National Wildfire Prediction Program. The program will provide guidance for fire managers throughout the country, assisting them to efficiently use limited fire-fighting resources. To achieve maximum cost leveraging, the program will build upon existing physics-based atmospheric and wildfire modeling efforts, a proven emergency response infrastructure, state-of-the-art computer science, and the world's most advanced supercomputers to create a comprehensive wildfire prediction system.

Keywords: wildfire, fire behavior, prediction, firefighting, NWPP

INTRODUCTION

Lawrence Livermore National Laboratory (LLNL) and Los Alamos National Laboratory (LANL) are proposing to develop and implement a National Wildfire Prediction Program (NWPP). This new national resource will combine and leverage components of the ongoing wildfire modeling effort at LANL and the existing National Atmospheric Release Advisory Center (NARAC) at LLNL. The combination of a world-class emergency-response infrastructure and state-of-the-science modeling capabilities allows, for the first time, a scientifically-

based national wildfire prediction capability to be envisioned.

The proposed National Wildfire Prediction Program (NWPP) will be designed to provide vital around-the-clock guidance to fire management planners throughout the country and could also predict fires of strategic interest around the globe. The NWPP will forecast the behavior of large wildfires that often occur simultaneously and compete for limited firefighting resources. In addition to real-time responses, the NWPP will contribute to three other key areas of wildfire management. The program will employ existing state-of-the-art capabilities that have been developed by LLNL for emergency response to incidents in which hazardous materials are released into the atmosphere. The NWPP will also make use of state-of-the-science wildfire prediction models developed at LANL that utilize fundamental weather, turbulence, and combustion theory. Because of this leveraging, the NWPP will have an initial capability within one year of project inception, and be fully operational within five years.

The Wildfire Threat

Wildfires present an ever increasing threat to human life, property, and natural resources. In 1994, for example, the total acreage affected by wildfires was somewhere in the range of 4 million acres—well over 6 thousand square miles, an area much larger than the

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state of Connecticut. That same year, the United States spent approximately \$1 billion in federal fire suppression efforts, lost 32 lives in the process, and saw wildfire crisis headlines for over a month. Because of the severity of the wildfire threat, the Secretaries of the Interior and Agriculture, Bruce Babbitt and Dan Glickman, respectively, chartered and signed *the Federal Wildland Fire Management Policy and Program Review Report*. The report was directive in nature, and in December, 1995 it was distributed to the Acting Director of the Bureau of Land Management, the Chief of the USDA Forest Service, the Director of the National Park Service, the Director of the U.S. Fish and Wildlife Service, the Deputy Commissioner of the Bureau of Indian Affairs, and the Director of the National Biological Service. The following three paragraphs summarize that report's conclusions.

The challenge of managing wildland fires in the United States is increasing in complexity and magnitude. The possibility of catastrophic wildfire now threatens millions of wildland acres, and our ability to plan for and suppress fires has been hindered by past successes. Almost one hundred years of fire suppression, coupled with other resource management activities, have altered vegetation patterns and caused the dangerous accumulation of highly flammable and decadent fuels, placing millions of acres of forests and rangelands at extremely high risk for devastating fires. Serious and potentially permanent ecological deterioration is possible where fuel loads exceed historical conditions. Enormous public and private values are at high risk, and our nation's capability to respond to this threat is becoming overextended. We are already seeing the effects through an increase in the number of fires and acres burned.

Wildland/urban interface protection is an especially important issue to the federal government because federally managed lands are often located adjacent to state lands and residential developments, where the population is increasing. In 1994 alone, an estimated \$250 - \$300 million were spent protecting the wildland/urban interface. The National Fire Protection Association estimates that, in addition to taking the lives of firefighters and citizens, wildfires have destroyed more than 9,000 homes since 1985. Federal firefighters are often called upon to assist local agencies in the wildland/urban interface and, in some cases, federal agencies are the only source of fire protection. Federal firefighting assistance also has been requested where there was no direct threat to federal lands. Federal response in the interface puts

federal firefighters at risk by spreading them thin and placing them in situations for which they may not be adequately trained or equipped. A fire burning in the interface often demands that scattered structures be protected at the sacrifice of resources elsewhere, causing significant fiscal liability to the federal, state and local governments as well as insurance carriers and property owners. Nearly every state has experienced wildland/urban interface fire losses. The fatal 1991 Oakland Hills, California fire, the Southern California fire siege of 1993, the 1994 Tye fire in Washington, the 1994 Chicken and Blackwell/Corral complexes in Idaho, and the 1998 Florida fires serve as examples of the complex challenges these fires pose.

To summarize the wildfire threat, the risk of catastrophic wildland fires is increasing, and the business of suppressing these fires is costly, time-consuming, and often dangerous to firefighters and the public. The problem is especially difficult in the wildland/urban interface, and this problem will escalate as the nation moves into the twenty-first century and people continue to relocate from urban to rural areas. Despite public expectations, when the combination of excessive fuel build-up, topography, extreme weather conditions, multiple ignitions, and extreme fire behavior occurs, our current capabilities are inadequate to immediately suppress every wildland fire. Most importantly, lives are being lost in our attempts to suppress these fires. It is essential that we do all we can to ensure our firefighters' safety and to increase their ability to efficiently contain and limit the spread of potentially devastating fires. This effort will require the best planning, training, and tools that our country can provide.

A powerful new fire management tool is now within the grasp of current science: an advanced, supercomputer modeling system that could predict wildfire behavior and provide a new sophisticated level of intelligence to fire managers.

A Major Advance: Coupled Wildfire-Weather Simulation

Historically, wildfire behavior models have been *empirically based*, and have used simple, prescribed sets of weather data, fuel conditions, and idealized terrain to predict heat release and fire spread. In reality, however, atmospheric conditions are constantly changing due to regional weather patterns, as well as to the intense heat of the fire itself; variable fuel distributions and conditions are the rule;

and topography is often extremely complex. Furthermore, the actual behavior of wildfires is determined by an almost unlimited number of possible interactions between many complex physical processes. In general, this behavior extends beyond the valid parameter space of simple empirical relationships based on a finite quantity of observational data. Because of these factors, an accurate, generalized wildfire behavior prediction system must have at its core *physics-based* models that explicitly represent the interactions between the atmosphere and the fire, and the effects of complex terrain on the atmosphere and on the fire.

Compared to traditional wildfire models, the NWPP will provide more accurate predictions for a much wider range of locations and weather conditions by using advanced physics-based models that simulate the fire-atmosphere system.

Benefits

Just as numerical weather models have greatly improved our ability to predict and prepare for severe storms, the NWPP's physics-based numerical models of the wildfire-atmosphere system will significantly improve our ability to anticipate fire behavior and to optimize the use of fire management resources. The NWPP's wildfire forecasting capability will reduce the risk to human life and property and lower the cost of wildfire suppression by providing critical information on the future location, intensity, and propagation rate of wildland fires. The NWPP will not only predict the behavior of untreated fires, but also will assist fire managers to optimize firefighting strategies by predicting the effectiveness of various firefighting actions. This information will facilitate the intelligent deployment of firefighting resources, and enhance the effectiveness of firefighting operations. The NWPP also will support important, non-emergency wildfire management activities.

FOUR CATEGORIES OF SERVICE ENVISIONED FOR THE NWPP

Throughout the development of the NWPP concept, we have conferred with members of the fire management community at the federal, state, and local level. Based on their valuable input, we have defined four general functional missions for the NWPP: real-time firefighting support, tactical planning for wildfire management, strategic planning for wildfire management, and firefighter training.

Real-Time Firefighting Support

Real-time firefighting support includes those services that must be rapidly provided to wildfire managers to assist them in making critical operational decisions regarding the deployment and utilization of firefighters and support equipment.

Predictions of Fire Behavior To provide guidance for real-time firefighting, the NWPP would rapidly collect data on terrain, weather, fire perimeter, and fuel conditions; run its interactive atmosphere-wildfire models on supercomputer platforms; and then rapidly disseminate predictions of fire and smoke behavior to fire managers anywhere in the country. This emergency response capability would be available twenty-four hours a day, as needed to support firefighting operations.

Predictions of Firefighting Effectiveness Because the NWPP models also will be capable of simulating the impact of firefighting operations on fire behavior, the NWPP could predict the relative effectiveness of various firefighting procedures (such as backfires, airtanker slurry drops, and helicopter water drops). These simulations could provide guidance to fire managers in selecting the critical locations to focus their limited resources and choosing the most efficient firefighting methods for specific fires.

Accessible via the Internet NWPP prediction products would be available over the Internet to authorized fire managers located at headquarters facilities, as well as to those deployed in the field, using a variety of communications systems including telephone lines, cell phones, and satellite communications. In addition to providing product delivery, the Internet connectivity could be used by fire managers to request NWPP support and to provide data to the NWPP Operations Center. ARAC successfully demonstrated the feasibility of two-way data communications to remote locations in a recent proof-of-concept exercise, by using an Internet-satellite link to provide *interactive* modeling support to a ship at sea.

Tactical Planning

We define tactical planning to be relatively short-term planning, but with longer notice and less urgency than would be required to respond to fires already in progress. Two examples of tactical planning that

could be supported by the NWPP are prescribed burn scheduling and fire threat analysis.

Prescribed Burn Scheduling Current wildfire management policy calls for a major increase in the number of acres burned annually by prescribed fires to achieve fuel management goals. To assist in the planning for these prescribed burns, the NWPP would be able to provide predictions of fire spread characteristics and of the atmospheric dispersion of smoke. This advance knowledge would enable fire planners to decrease the risk of prescribed fires getting out of control and of violating air-quality-standards.

Fire Threat Analysis In another type of tactical planning support, the NWPP could use its simulation capabilities to assess the relative risks of fire at various locations during periods of increased fire threat. This information could be used by fire managers to intelligently predeploy firefighting resources in a risk-prioritized manner.

Strategic Planning

By strategic planning, we refer to long-term (time scales of months to many years) wildfire management planning. Two examples of strategic planning activities that could be supported by the NWPP are long-term forest management and community development planning.

Evaluation of Forest Management Options To support long-term forest management planning, NWPP simulations using climatological weather data and hypothetical fuel characteristics could be used to evaluate the impact of various forest management options (such as tree-thinning, prescribed burn programs, or underbrush clearing) on future wildfire risks and consequences.

Community Development Planning NWPP simulations could be used for guidance in community development planning in the urban-wildland interface. Simulation results could assist in determining optimal locations for new homes, open areas and greenbelts (for fire breaks), and community infrastructure.

Firefighter Training

As a training tool, NWPP wildfire simulations could be used to acquaint students with fire behavior characteristics for a wide range of scenarios, accelerating the process of developing a mature experience base. For example, after specifying the location (including high-resolution terrain information) of the fire, students could vary the weather and fuel conditions to help them understand their impact on fire behavior. Students could also use the system to better understand the effectiveness of various firefighting methods for different terrain, weather, and fuel conditions.

A COMPLEX SCIENTIFIC CHALLENGE

Accomplishing these objectives requires an advanced, operational fire simulation capability. Interactions between wildfires and local weather and terrain are highly complex (see Figure 1). Weather conditions (winds, air temperature, humidity, and precipitation) influence fuel flammability and largely determine the risk of fire ignition and the rate of the resulting combustion. In addition, the wind speed and direction determine the rate of fire spread and amount of firebrand transport from which new fires can be ignited. Weather conditions also determine the location and concentration of smoke plumes, which may interfere with ground-based and aerial firefighting operations and cause health hazards downwind. In turn, the heat from fires of medium to intense magnitude causes rising air currents that can strongly modify local airflow patterns. These strong updrafts of heated air above fires often cause the formation of liquid-water (and sometimes ice-bearing) convective "cap" clouds. Processes within these clouds interact with, alter, and may even promptly remove smoke particles, further affecting downwind smoke conditions.

The accurate prediction of wildfire behavior must account for these complex fire-atmosphere interactions. This requirement can be best accomplished by a computer-based predictive numerical model of the fire-atmosphere system.

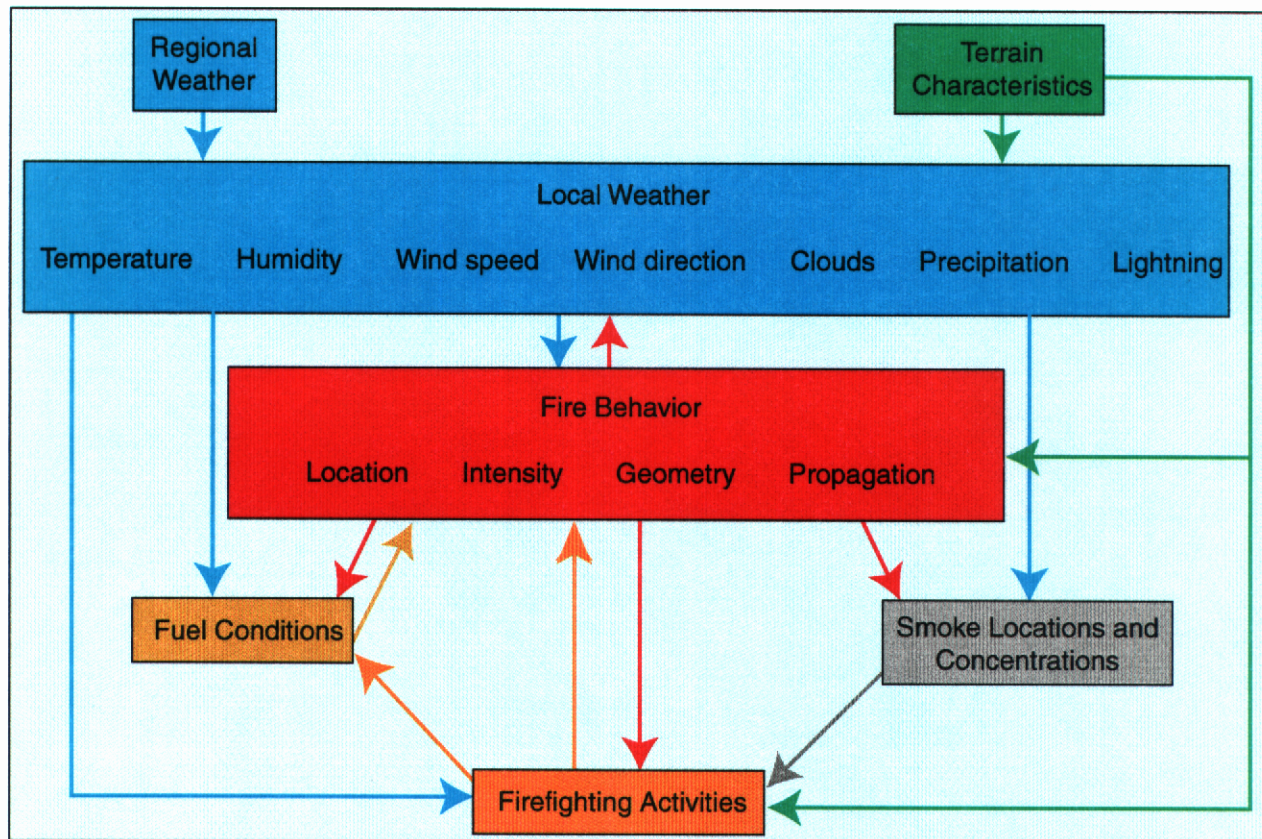


Figure 1. There are strong, complex interactions between wildfires, the local and regional weather, and the terrain. These fire-atmosphere feedback processes and terrain effects must be properly accounted for in a scientifically-based fire prediction system.

MEETING THE CHALLENGE BY LEVERAGING ON EXISTING AND EMERGENT CAPABILITIES

Developing computer models that can accurately predict the behavior of wildfires by including the strong coupling between the fire and atmosphere requires advancing far beyond the operational fire modeling capabilities that exist today. This capability is absolutely required, however, for planning the safest and most effective fire suppression strategies.

The proposed National Wildfire Prediction Program maximizes the return on the public's investment by leveraging on existing the research and real-time-operations capabilities at two national laboratories to create a cost-effective, national resource. The NWPP will combine LANL's state-of-the-science wildfire models, ARAC's extensive emergency response infrastructure, and the Department of Energy's

unsurpassed computing resources. Using the LANL models takes advantage of nearly four years of intensive research and development toward a comprehensive wildfire prediction system. Integrating the NWPP with ARAC at LLNL provides the availability of ARAC's experienced emergency response scientists, computer scientists, technical support staff, regional and local atmospheric prediction models, advanced atmospheric transport and dispersion models, geographical and other databases, emergency operations system software, dedicated computers, data communications systems, and the modern building facilities of the National Atmospheric Release Advisory Center.

Interactive Wildfire-Weather Simulation Capabilities

The intensive research effort at LANL in coupled weather/wildfire modeling has been underway for the past four years as part of a broader initiative to predict

the unfolding of crisis events. A diagram of the LANL wildfire modeling framework is shown in Figure 2. Within the main flow of the diagram are three components, the Regional Atmospheric Modeling System (RAMS), originally developed at Colorado State University; the model for High resolution and strong GRADient applications (HIGRAD), a code written by Reisner at LANL; and FIRETEC, a physics-based fire behavior model, one of the first of its kind, developed by Linn and Harlow at LANL. RAMS is a widely-used, comprehensive

atmospheric modeling system based upon fundamental conservation relationships for atmospheric mass, momentum, and energy. Like the COAMPS model, which currently runs on a daily basis at LLNL, RAMS is used to predict the state of the atmosphere (winds, temperature, pressure, humidity, and precipitation) at any given time from the present out to several days, and from regional scales encompassing most of the United States down to very local scales covering a particular watershed.

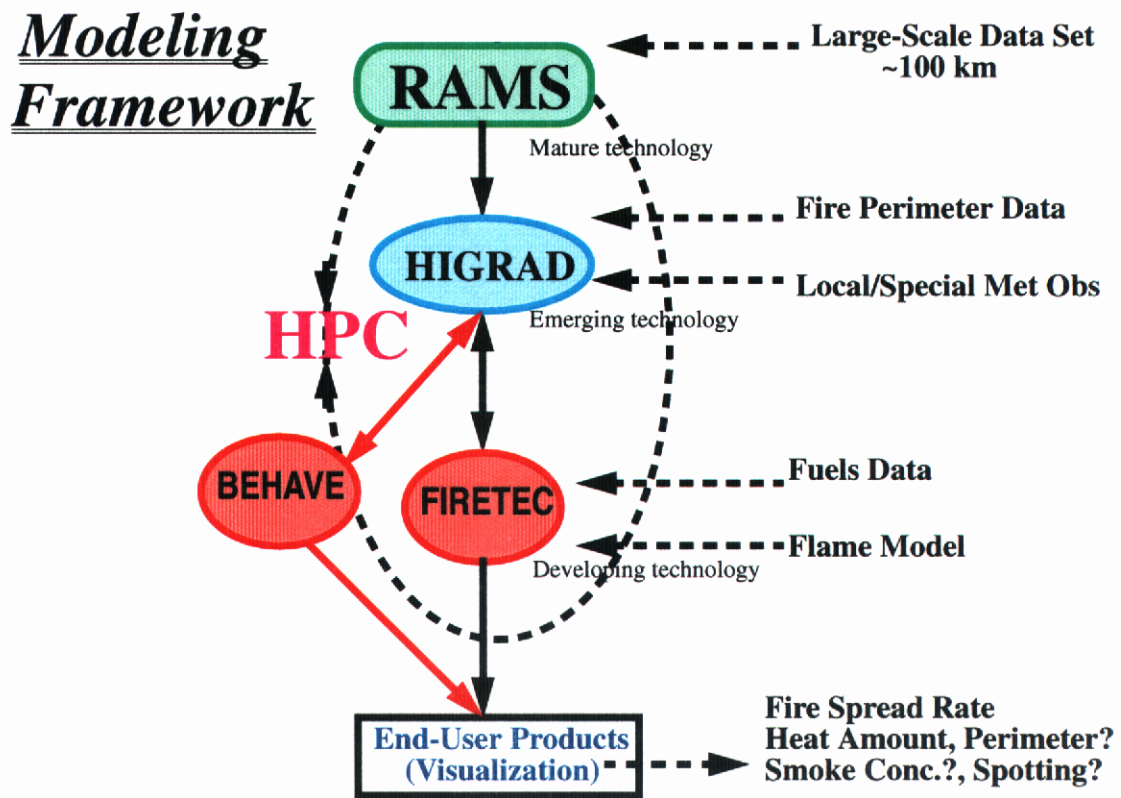


Figure 2. Flow diagram schematically illustrating interactions between the current LANL wildfire model components. In the NWPP system, RAMS will likely be replaced by COAMPS, a very similar weather prediction model used to support ARAC operations.

The HIGRAD model is a generalized atmospheric dynamics code that has been developed using a state-of-the-art numerical formulation. These numerics can deliver highly accurate weather simulations at

extremely high (i.e., fine) spatial and temporal resolution (down to 1 meter). High resolution is a primary requirement for capturing the critical weather/fire feedback process.

FIRETEC is a fire behavior model developed at LANL that predicts fire spread based upon a fundamental treatment of the combustion process. This model can be used to understand the driving mechanisms of fire propagation in ways that far exceed the capability of empirically-based fire models like those presently in widespread use in the fire community. FIRETEC is still in the early stages of development and offers enormous potential to further understand the fundamentals of wildfire behavior and to build this understanding into improved versions of operational models in the future.

The three primary model components shown in Figure 2 are enveloped by a dashed line, indicating that they are presently targeted at high performance computing and communications (HPCC) architectures. Also included in the flow diagram is the US Forest Service's BEHAVE system, which has been coupled to HIGRAD and lies outside the HPCC environment, due to its low computational demands.

The coupled HIGRAD/BEHAVE model has been used to simulate weather and fire for the 1994 South Canyon, Colorado (see Figures 3 and 4) and 1996 Calabasas (Los Angeles County) wildfire incidents. The results to date are very encouraging with respect to the spread rate variability and heat intensity of the simulated fires when compared with field observations. In particular, we have found that coupling between the atmosphere and fire is crucial for obtaining realistic fire propagation up steep slopes.

At the end of the flow diagram lies the end-user product. This presently includes graphical output and scientific visualization images for understanding detailed physical processes within the simulation. For the NWPP, the end-user product will include a host of pre-defined products tailored to the needs of fire managers, such as predicted hourly fire perimeter and fire intensity plots, more frequent updates of the probability of blow-ups and other time-critical emergencies, and estimates of smoke distributions. To the right of each model component in Figure 2 are dashed arrows indicating the primary data sets necessary for each part of the model. They include both static and frequently changing data that will be continuously maintained by the NWPP and made available for model initialization and validation.

Also shown is a flame model which can provide details to FIRETEC on the physics and chemical reactions occurring in the combustion process. By collaborating with Sandia National Laboratory (SNL), we can improve the representation of the combustion processes in FIRETEC based on tests with SNL's explicit flame model. This is a key tool for gaining new insight into fire physics at the highest level of detail. New methodologies will be developed to incorporate this knowledge into FIRETEC and eventually into NWPP fire models.

Smoke Simulation Capabilities

Predictions of smoke concentrations could be useful for planning ground and airborne firefighting operations, and also for understanding downwind effects, such as impacts on human health. Lawrence Livermore National Laboratory has a strong background in modeling the atmospheric effects of fires, and particularly in the transport, diffusion, and precipitation scavenging of smoke. LLNL was a key participant in the Climate Effects of Nuclear War ("Nuclear Winter") Research Program during the mid-1980s. Over a period of several years, a team of LLNL atmospheric scientists examined the problem and conducted numerical simulations on scales ranging from the almost instantaneous interactions of tiny smoke particles with cloud droplets, all the way to long-term global climate impacts. Much of this research effort was directed at the development, validation, and application of numerical models to predict the behavior of the atmosphere in the immediate vicinity of intense fires, and to predict the fate of the smoke emitted from these fires.

In addition to research on smoke behavior, ARAC (see the following section for additional information on ARAC) has experience predicting atmospheric smoke dispersion for real-time operations. Following Operation Desert Storm, ARAC provided twice-daily predictions of smoke dispersion from the burning oil wells in Kuwait. These forecasts were disseminated to several federal agencies and to approximately a dozen countries in the Persian Gulf region. More recently, ARAC predicted the dispersion of smoke from a massive tire dump fire near Tracy, California (see Figure 5), from which the smoke rose to approximately 6,000 feet above ground level. State agencies used the ARAC's calculations to assess the potential health effects of the smoke.

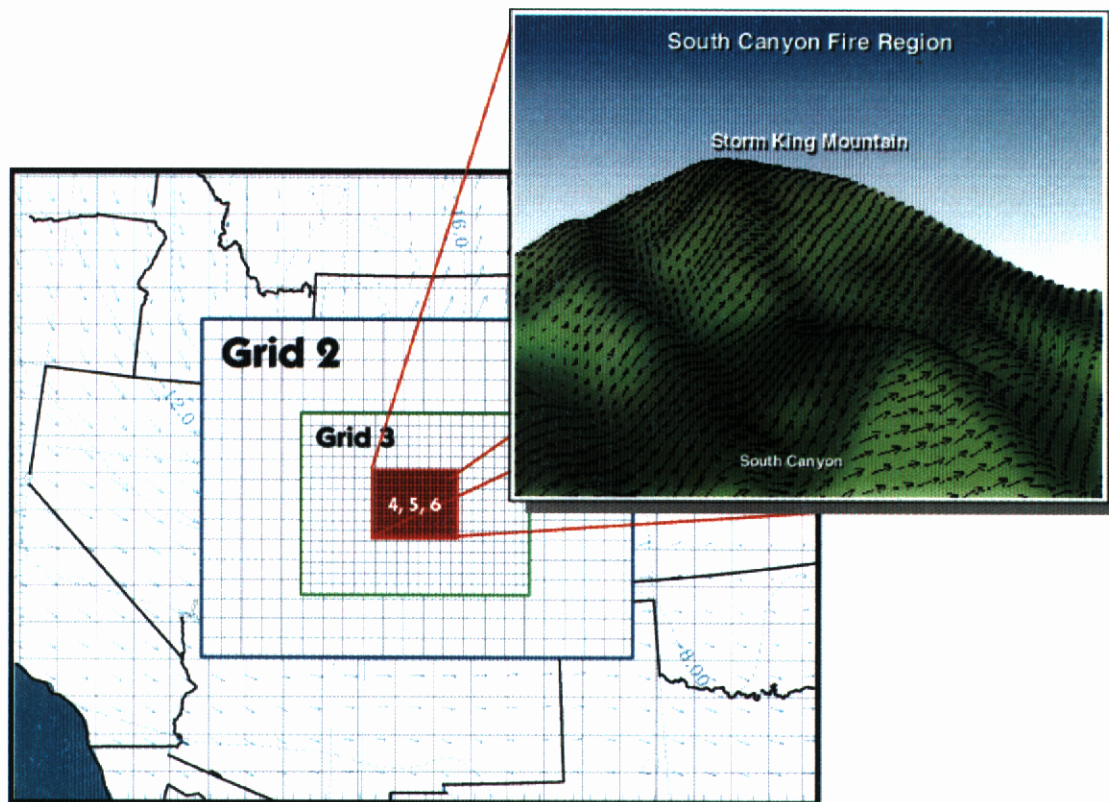


Figure 3. Grid structure and fine-scale simulated winds for the 1994 South Canyon, Colorado wildfire case study.

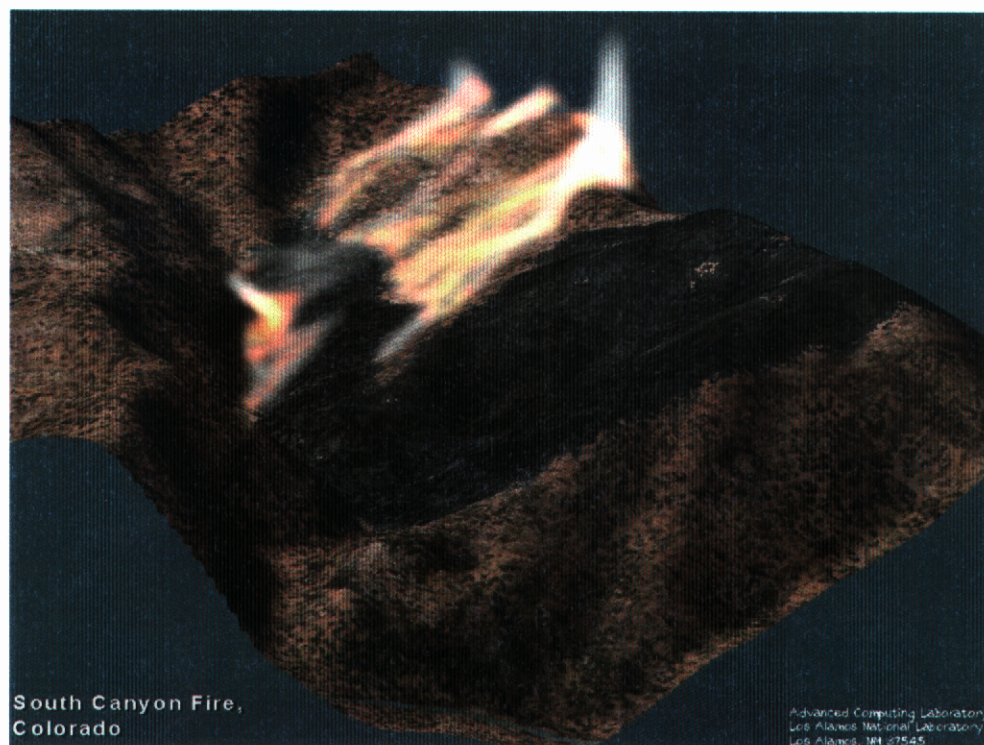


Figure 4. Simulation of the 1994 South Canyon, Colorado wildfire using the coupled HIGRAD/BEHAVE model.



Figure 5. ARAC simulation and corresponding aerial photograph of the actual smoke plume from the August, 1998 Tracy, California tire disposal facility fire.

Emergency Operations Capabilities

The Atmospheric Release Advisory Capability at LLNL is a centralized federal program with over 20 years of experience supporting federal, state, and local emergency response planners by providing real-time emergency assessments (analyses and predictions) of the impacts of inadvertent or intentional releases of hazardous materials into the atmosphere. ARAC is a complete emergency response system, consisting of highly trained personnel (operations scientists, research scientists, computer scientists, engineers, and technicians) with a vast experience base in the development and operation of real-time emergency response systems, continually updated computer models, extensive databases, redundant data collection systems, centralized and remote computer and communication systems, and a modern operations center. Key examples of existing subsystems that ARAC will provide to the NWPP include its real-time global weather data acquisition system, global terrain elevation data system, global mapping system, and in-house weather prediction system. Originally

tasked to respond to radiological emergencies, ARAC is now also capable of responding to atmospheric releases of toxic chemicals and biological agents, and even to volcanic eruptions. Since 1974, ARAC has responded to over 70 domestic and international incidents, working closely with local and state officials, major departments of government (Department of Defense, Department of Energy, Department of State, etc.), and numerous foreign governments. In addition, ARAC has participated in over 700 exercises during this time period. The basic concept of ARAC is depicted in Figure 6. Figure 7 highlights the extremely high leveraging that will be obtained by co-locating the National Wildfire Prediction Program with ARAC.

Supercomputing Capabilities

Computational resources to perform the wildfire predictions are an important consideration. Both LANL and LLNL have a long history as leaders in the use of advanced computers. The predictive simulation of wildfires is an extremely computationally intensive

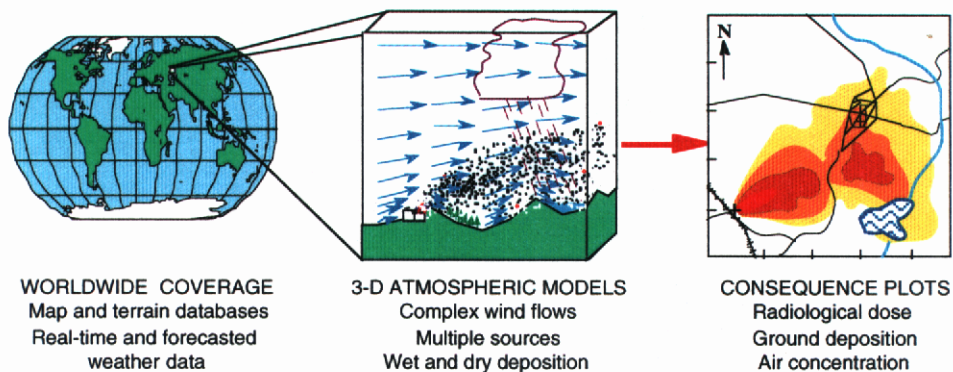


Figure 6. Basic concept of the ARAC emergency response capability. ARAC rapidly accesses world-wide, multi-scale terrain and geographical information; world-wide, real-time atmospheric observations and forecasts; and extensive hazardous material databases; then uses a powerful suite of numerical prediction models to quickly predict the toxic effects of nuclear, chemical, and biological materials released into the atmosphere. This information can be instantly disseminated to emergency response organizations world-wide.

task, because it must include physically-based representations of regional and local-scale atmospheric processes, fine-scale turbulent airflows, complex interactions between fire dynamics and atmospheric dynamics, and for some cases, cloud-smoke and precipitation-smoke interactions. Moreover, these processes must be simulated much faster than they occur in the real world in order for the predictions to be useful for operational support. This task will require access to advanced parallel processing machines. As part of the DOE's commitment to HPCC, both LANL and LLNL have recently acquired clusters of multiple-processor supercomputers under the Accelerated Strategic Computing Initiative (ASCI) and other programs. This computing environment allows for an entirely new paradigm in fine-scale computing of difficult physics problems. With computers on this scale, a forecasting capability can now be achieved using very detailed fire prediction models. Access to parallel computers has been key to LANL's initial success in wildfire modeling, because it enables detailed testing and validation at full-scale. These machines will accelerate the development of research to better understand coupled weather/wildfire behavior and permit the transfer of this research into the NWPP's operational models.

In the first 3 years of the NWPP's development, computer resources for model research, development, and validation will be provided by Los Alamos National Laboratory. This could amount to as much as a \$1.5 million dollar benefit to the NWPP.

COLLABORATIONS WITH THE WILDFIRE COMMUNITY

As part of the four-year history of Los Alamos' fire modeling, fruitful collaborations have been developed with several fire management agencies. These collaborations include 1) joint research endeavors with the U.S. Forest Service's Pacific Southwest Station Riverside Fire Laboratory; 2) a fire modeling partnership with Los Angeles County Fire Department to use physics-based wildfire models for planning, training, and operational purposes in the wildland/urban interface surrounding Los Angeles; and 3) developing prescribed burn/model validation exercises at the Kennedy Space Center in Florida with the Dynamac Corporation, the U.S. Fish and Wildlife Service (Merritt Island National Wildlife Refuge), the NASA Kennedy Space Center, and the U.S. Air Force's Cape Canaveral Air Station. These collaborations provide an opportunity to understand the needs of fire managers and obtain real-world fire expertise.

Throughout the development of the NWPP concept, we have coordinated with leaders in the fire management community at the local, county, state, and federal level. Many of these individuals have provided valuable comments and suggestions which have been incorporated in to the NWPP concept and implementation plan. We will continue to expand these collaborations and work closely with fire

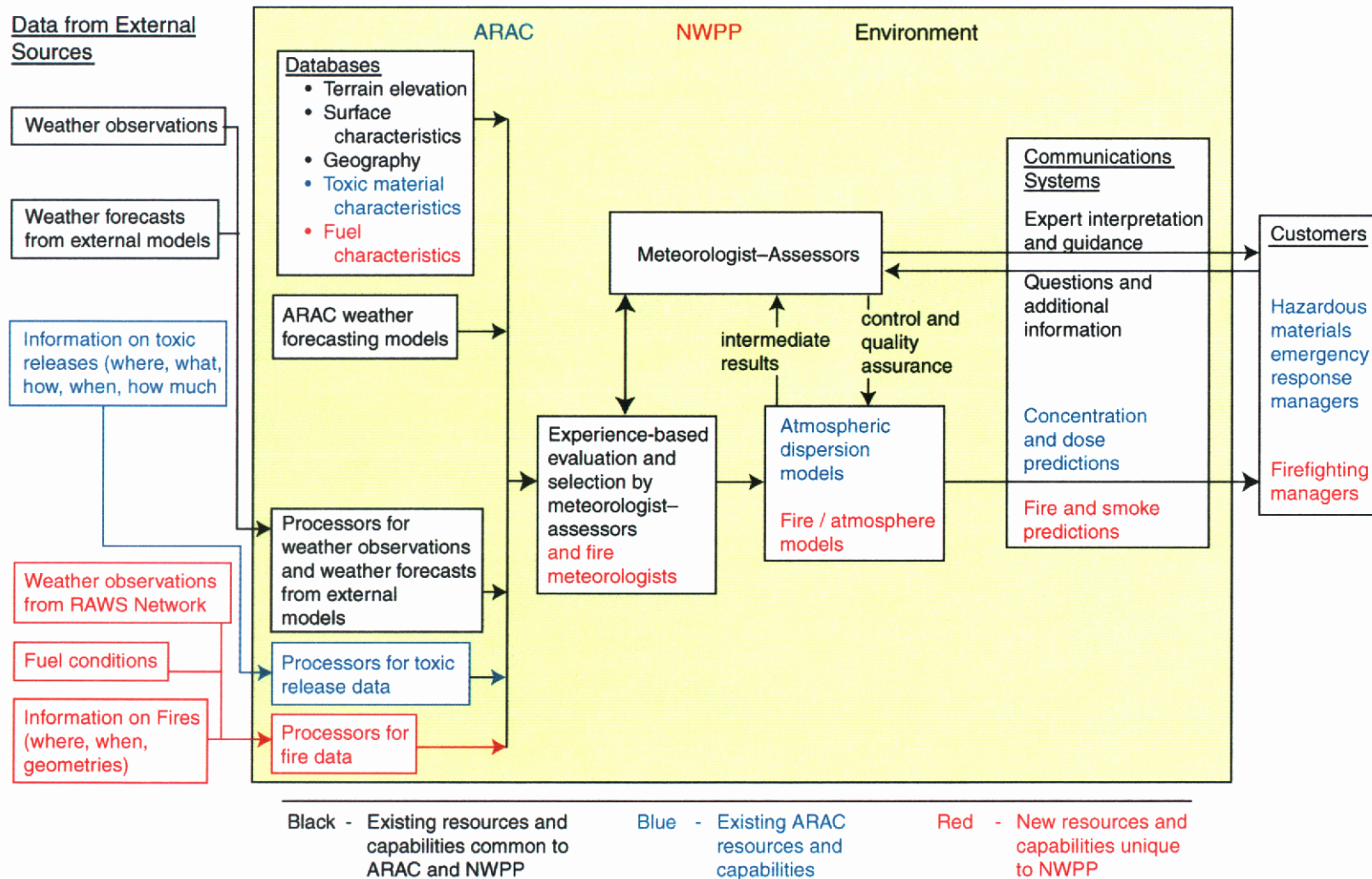


Figure 7. The most cost effective way to achieve a national wildfire prediction capability is to co-locate the National Wildfire Prediction Program (NWPP) with ARAC and leverage off ARAC's proven experience base, capabilities, and resources. This figure shows the identical and parallel features of ARAC and the proposed NWPP. Already existing capabilities common to both ARAC and NWPP are indicated in black, existing capabilities unique to ARAC are indicated in blue, and the new capabilities required for NWPP are indicated in red.

managers from various agencies through the course of the NWPP program's development.

IMPLEMENTATION

The models will be adapted for operational application and implemented in the NWPP using a phased approach, in which increasingly complex tools will be gradually implemented to achieve an increasingly accurate predictive modeling system. Specifically, three versions of a Coupled (weather and wildfire) Fire Modeling (CFM) system, with sequentially increasing complexity, will be implemented over a five-year period, beginning in program year 1 with CFM version 0. Subsequent deliveries of CFM versions 1 and 2 will occur in program years 3 and 5, respectively. Each model version will be continuously validated and refined up to the time that it becomes frozen for operational purposes. Version 0 of the coupled fire model will be based upon a robust formulation of the HIGRAD/BEHAVE system discussed above. CFM version 1 will incorporate the HIGRAD/FIRETEC modeling framework and include adaptive grids that will give finer spatial resolution along the fireline. The use of adaptive grids will result in a tremendous decrease in computational burden and will compensate for the additional computing resources needed to support the complexity of the FIRETEC code. Also included in version 1 will be submodels representing radiative transfer from the fire, firebrand transport, and fire spotting. CFM version 2 will have additional complex physics, including pyrolysis and the emission of moisture, hydrocarbons, soot, and ash from the combusting fuel elements. These emissions constitute the smoke production and will be used to assess local smoke effects. The smoke emission information will be combined with a regional smoke transport model to provide an end-to-end modeling system that can predict, in a physics-based and accurate way, both fire progression and smoke concentration and transport.

SUMMARY AND CLOSING REMARKS

If funded, the proposed National Wildfire Prediction Program will provide real-time support for firefighting operations nationwide, by providing highly accurate predictions of wildfire behavior and smoke dispersion, using advanced techniques previously unavailable to the wildfire management community. The NWPP will also support tactical and strategic planning for wildfire management, and

provide an innovative computer-based training tool for firefighters.

The NWPP will be highly cost-leveraged on existing and emergent capabilities at Lawrence Livermore and Los Alamos National Laboratories. A detailed cost analysis indicates there would be a five- to ten-fold cost increase if a comparable wildfire prediction system had to be developed "from scratch". To further put the cost into perspective, our analyses show that *the estimated average annual cost for developing, implementing, and operating the NWPP over the first five-years of its lifetime is approximately one-third of one percent of the 1994 federal expenditures for wildfire suppression, and is less than one percent of the costs incurred during the five-week period of the 1998 Florida wildfires.*

We believe the NWPP can make a major contribution to the safety and effectiveness of wildfire management, and we look forward to working closely with the wildfire management community to make it a reality.

ACKNOWLEDGEMENT

Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under contract No. W-7405-Eng-48.